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(54) Improved process for selective deposition of tungsten on semiconductor wafer.

(57) A process and apparatus for the selective deposition of tungsten or similar materials on a masked semiconductor wafer (100) comprises cleaning the surfaces of the wafer (100) in an air-tight cleaning chamber (10), then transferring the cleaned wafer to a vacuum deposition chamber (40) such as a CVD chamber for selective deposition of tungsten etc. thereon without exposing the cleaned wafer (100) to conditions which would recontaminate the cleaned wafer (100) prior to said deposition, and then selectively depositing tungsten etc. on the unmasked surfaces of the cleaned wafer (100).

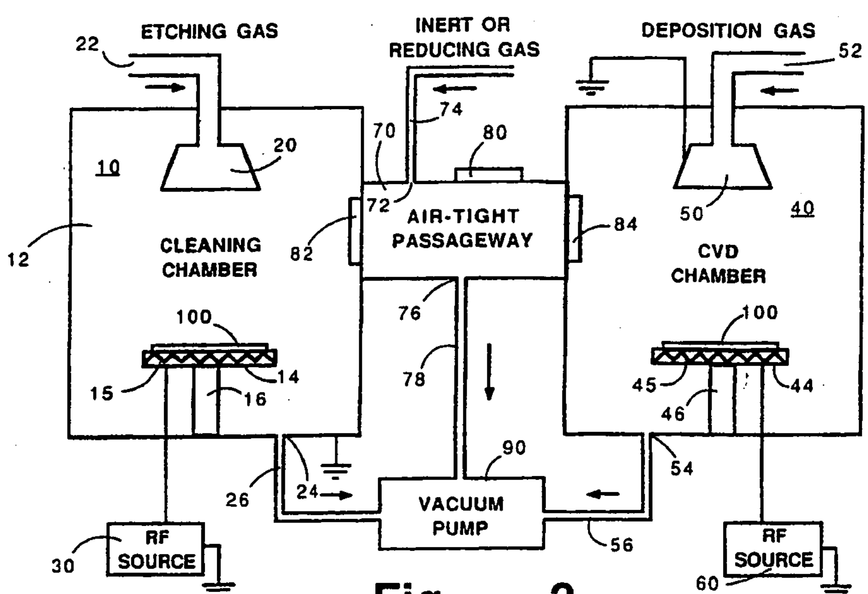

Fig 2

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IMPROVED PROCESS FOR SELECTIVE DEPOSITION OF TUNGSTEN ON SEMICONDUCTOR WAFER

Background of the Invention

1. Field of the Invention

This invention relates to the processing of semiconductor wafers. More particularly, this invention relates to improvements in the process of forming a selective coating of tungsten on a semiconductor wafer having a patterned mask thereon.

2. Description of the Related Art

In the processing of semiconductor wafers to selectively deposit tungsten over layers of, for example, aluminum, silicon, tungsten, or titanium nitride, having patterned masks thereon, it is important that the surfaces be free of any contamination, including moisture or any oxides such as, for example, aluminum oxide, silicon oxide, tungsten oxide, and titanium oxide.

Such contamination, if present can either mask or inhibit nucleation on the unmasked areas where the selective tungsten deposit is desired, or may provide unwanted nucleation sites on masked portions of the wafer.

The semiconductor wafer surfaces are, therefore, usually cleaned to remove all contamination and moisture prior to such a selective deposit. Such cleaning includes both the surfaces to be deposited on, as well as the mask surfaces.

Such cleaning is conventionally carried out by wet cleaning, for example, using an HF etch (for oxide removal) or a H_2SO_4:H_2O_2:H_2O cleaning solution (for removal of organics) to remove the contaminants, including oxides, from both the unmasked surfaces as well as the surfaces of the mask.

While such wet cleaning of the masked and unmasked areas of the wafer surface does result in removal of the contaminants, including oxides, from the mask surfaces as well as the unmasked surfaces, moisture is not necessarily removed. More importantly, however, is the subsequent exposure of the cleaned surfaces to ambient conditions during the transfer of the cleaned wafer from the wet cleaning apparatus to a vacuum deposition apparatus suitable for the selective deposition of tungsten on the unmasked areas of the wafer by deposition techniques such as chemical vapor deposition (CVD) or plasma-assisted CVD. Such exposure can interfere with the subsequent tungsten deposition process, including the reproducibility of the results from wafer to wafer.

It would, therefore, be beneficial to provide an improved process for the selective deposition of tungsten on a semiconductor wafer wherein the masked and unmasked surfaces could be cleaned to remove contaminants such as oxides and moisture and the selective tungsten deposition then carried out without intervening exposure of the cleaned surfaces of the wafer to further contamination.

Summary of the Invention

It is, therefore, an object of this invention to provide an improved process for the selective deposition of tungsten or similar materials on a masked semiconductor wafer.

In principle, the invention comprises cleaning the surfaces of the wafer in an air-tight cleaning chamber and then transferring the cleaned wafer to a vacuum deposition chamber for selective deposition of tungsten etc. thereon without exposing the cleaned wafer to conditions which would recontaminate the cleaned wafer prior to the deposition.

According to another aspect this invention provides an improved process for the selective deposition of tungsten or similar material on a masked semiconductor wafer which comprises cleaning the surfaces of the wafer in a cleaning chamber under vacuum and then transferring the cleaned wafer from the cleaning chamber to a CVD chamber through a passage between the respective chambers in which the atmosphere is controlled to exclude moisture or oxidizing gases to permit selective tungsten deposition on the clean surfaces on the wafer without exposing the cleaned wafer to conditions which would recontaminate the cleaned wafer prior to the deposition.

According to another aspect this invention provides an improved process for the selective deposition of tungsten or similar material on a masked semiconductor wafer which comprises cleaning the surfaces of the wafer in a cleaning chamber under vacuum using a halogen-containing gas to remove contaminants including oxides and moisture and then transferring the cleaned wafer from the cleaning chamber to a CVD chamber through a passage between the respective chambers maintained under vacuum to exclude moisture or oxidizing gases to permit selective tungsten deposition on the clean surfaces on the wafer without exposing the cleaned wafer to conditions which would recontaminate the cleaned wafer prior to the deposition.

According to another aspect this invention provides an improved process for the selective deposition of tungsten or similar material on a masked semiconductor wafer which comprises cleaning the surfaces of the wafer in a cleaning chamber under vacuum using a halogen-containing gas and a plas-

ma to remove contaminants including oxides and moisture and then transferring the cleaned wafer from the cleaning chamber to a CVD chamber through an air-tight passageway between the respective chambers in which one or more inert or reducing gases are present and moisture or oxidizing gases are excluded to permit selective tungsten deposition on the clean surfaces on the wafer without exposing the cleaned wafer to conditions which would recontaminate the cleaned wafer prior to the deposition.

Further features and advantages of the instant invention will be apparent from the following description and accompanying drawings.

Brief Description of the Drawings

Figure 1 is a flow sheet illustrating the process of the invention.

Figure 2 is a diagrammatic illustration of the relationship between the vacuum cleaning chamber and the CVD chamber for the selective deposition of tungsten showing the transfer passage between the two chambers which permits transfer of the cleaned wafer directly to the vacuum deposition chamber without exposure of the cleaned wafer to ambient conditions.

Detailed Description of the Invention

Referring now to Figure 2, an apparatus suitable for the practice of the invention is shown comprising a cleaning chamber 10 and a chemical vapor deposition (CVD) chamber 40 which are interconnected by an air-tight passageway 70 which permits movement of the cleaned wafer from cleaning chamber 10 to CVD chamber 40 without contamination of the cleaned wafer.

Cleaning chamber 10 includes therein a wafer support or base member or cathode 14 which may be supported by a pedestal 16 and on which a semiconductor wafer 100 is placed during the RIE cleaning process. Chamber 10 also includes a gas distribution or "showerhead" member 20 through which an etching or cleaning gas is fed into the chamber through a pipe 22 from a gas source (not shown). Base member 14 and wafer 100 thereon are maintained at a temperature within a range of from about 20 to about 100° C, preferably within a range of from about 20 to about 80° C, during the cleaning step by a heater 15 within cathode 14.

Cleaning gases may be fed into chamber 10 through distribution member 20. Such cleaning gases preferably will be specifically selected for the particular surface to be cleaned. For example, for cleaning aluminum or aluminum oxide surfaces on the wafer, a halogen-containing gas such as BCl_3may be used; while for cleaning silicon surfaces (to remove silicon oxides) NF_3 or SF_6 may be used. For tungsten, the use of hydrogen (to remove tungsten oxide) is preferred. In each case, the gas may be further diluted with a carrier gas as will be described below. However, at least in the case of hydrogen, the cleaning gas may be used without dilution by a carrier gas.

The cleaning gas is mixed with a carrier gas such as, for example, argon or helium, or a mixture of same, in a ratio of cleaning gas to carrier gas of from about 1:20 to about 20:1, in parts by volume. The cleaning gas is flowed into the cleaning chamber at a rate within a range of from about 5 to 100 standard cubic centimeters per minute (sccm); while the carrier gas is flowed into the cleaning chamber at a rate within a range of from about 5 to 1000 sccm, depending upon pump capacity.

Chamber 10 is further provided with a gas evacuation port 24 through which gas is evacuated from chamber 10 through pipe 26 to a vacuum pump 90 to maintain a pressure in chamber 10 within a range of from as low as about about 1 milliTorr to as high as atmospheric pressures (760 Torr) when no plasma is used. When a plasma is used in connection with the gas, the pressure will preferably range from about 1 to about 500 milliTorr.

While in some instances, the cleaning gas may be used by itself to clean the wafer, the use of a plasma with the cleaning gas will be advantageous, at least in some instances. An rf source 30 is, therefore, connected to base 16 to permit ignition of a plasma between base 16 and grounded walls 12 of chamber 10. When a plasma is used in the cleaning step, the power level of the plasma should be maintained within a range of from about 1 to about 1000 watts, preferably within a range of from about 10 to about 200 watts, and most preferably within a range of from about 10 to about 100 watts.

For the cleaning of aluminum surfaces, the use of reactive ion etching (RIE) may be preferred using the aforesaid mixture of argon and BCl_3gases.

Wafer 100 may be admitted into the apparatus through a first slit valve 80 in passageway 70 from which it may be placed in RIE chamber 10 through a second slit valve 82 located between RIE chamber 10 and passageway 70. Another slit valve 84 provides communication between passageway 70 and CVD chamber 40. Further details of such slit valves, as well as other aspects of the vacuum apparatus, may be found in Toshima U.S. Patent 4,785,962, assigned to the assignee of this invention and cross-reference to which is hereby made.

An exit or evacuation port 76 connects passageway 70 with vacuum pump 90 via pipe 78 to permit maintaining a pressure in said passageway within a range of from about 10^{-2} to about 10^{-}-

^{5}milliTorr, practically from about 10^{-2} to about 10^{-3}milliTorr. Higher pressures may be used, for example, by introducing a non-oxidizing gas into passageway 70 as long as the partial pressure of any impurities in the gas does not exceed about 10^{-2} milliTorr.

For this purpose, passageway 70 may also be provided with an entrance port 74 through which one or more non-oxidizing gases, i.e., inert or reducing gases, such as, for example, helium, argon, nitrogen, or hydrogen, or mixtures of same, may be flowed into passageway 70 via pipe 76 from a gas source (not shown).

The amount of flow of such non-oxidizing gases into passageway 70 is not crucial, since the purpose is merely to prevent exposure of the cleaned wafer and mask surfaces to moisture and/or other oxidizing atmospheres prior to admission or passage of wafer 100 into CVD chamber 40. Usually a flow rate of at least about 20 sccm, preferably about 100 sccm, will suffice.

After wafer 100 is placed on base member 14 and brought to the desired temperature, the cleaning gases are flowed into chamber 10 and the plasma ignited, when a plasma is used. The cleaning step should be carried out for a time period within a range of from about 5 to about 300 seconds, preferably from about 20 to about 300 seconds. Longer periods may be used, but may not be needed or be economically feasible.

After the cleaning step is completed, a nonreactive gas such as, for example, a carrier gas, e.g., argon, or a reducing gas such as hydrogen, may be optionally flowed through chamber 10 (without the cleaning gas) for an additional 5 to 30 seconds (or longer) at a rate within a range of from about 5 to about 1000 sccm (preferably about 20 to about 100 sccm when low pressures, i.e., 500 millitorr or lower, are used in the cleaning step) to flush out any residues remaining in chamber 10 from the cleaning step. If a plasma has been used during the cleaning step, it may be left on during this step to assist in removal of any residues remaining in cleaning chamber 10.

After the cleaning and optional flushing steps are completed, wafer 100 is removed from chamber 10 back into passageway 70 via slit valve 82. Wafer 100 is then directly admitted into CVD chamber 40 through slit valve 84 so that, in accordance with the invention, wafer 100 is not exposed to moisture or oxidation or any other contaminants between the cleaning step in cleaning chamber 10 and the tungsten deposition step in CVD chamber 40.

It should be noted that for best results, prior to moving the cleaned wafer into the chamber, the CVD chamber should be cleaned to remove any tungsten residues remaining therein from previous depositions. The CVD chamber, and in particular the susceptor, may be cleaned using an NF_3 plasma followed by an H_2 plasma. Details of such a cleaning process may be found in Chang U.S. Patent Application Serial No. 398,689, assigned to the assignee of this invention and cross-reference to which is hereby made.

CVD chamber 40 may comprise any conventional CVD apparatus. For example, while CVD chamber 40 is depicted in Figure 2 as a rectangular chamber, it may comprise a cylindrical tube such as the quartz tube CVD chamber described in Miller U.S. Patent 4,794,019, assigned to the assignee of this invention and cross-reference to which is hereby made.

Wafer 100 may be placed on a base or susceptor 44 which may be supported in chamber 40 by a pedestal 46. A mixture of a tungsten-containing gas such as, for example, WF_6, and a reducing gas such as H_2 or SiH_4, is flowed into chamber 40 via pipe 52 and showerhead 50 at a rate within a range of from about 20 to about 200 sccm. When the reducing gas is hydrogen, the WF_6:H_2 ratio should range from about 1:50 to about 1:1000 in parts by volume. When the reducing gas is SiH_4, the ratio of WF_6 to SiH_4 should range from about 10:1 to about 1:1.5, in parts by volume. The mixture of tungsten-containing gas and reducing gas may be accompanied by a carrier gas, such as helium or argon, flowing at a rate within a range of from about 1000 to 3000 sccm.

CVD chamber 40 is also provided with an exit port 54 which is connected to vacuum pump 90 to maintain a pressure in CVD chamber 40 during the deposition within a range of from about 1 milliTorr to about 760 Torr, preferably from about 1 milliTorr up to about 200 milliTorr.

During the subsequent selective tungsten CVD process, the wafer and base or susceptor 44 on which it rests may be maintained at a temperature within a range of from about 350 to about 500°C, when using H_2 as the reducing gas, and and within a range of from about 200 to about 400°C, when using SiH_4 as the reducing gas, by a heater 45 mounted within base 44.

The selective tungsten deposition is then carried out in CVD chamber 40 for an amount of time sufficient to deposit the desired thickness of tungsten on the exposed surfaces of wafer 100.

The following examples will serve to further illustrate the improved tungsten deposition process of the invention.

Example I

Several patterned silicon wafers, having silicon dioxide masks and different thicknesses of native oxide on exposed silicon surfaces, were processing

by inserting each sequentially into the plasma etching chamber of an Applied Materials Series 5000 Apparatus and placing the respective wafer on a support base therein. Each wafer and the support base were heated to a temperature of 30° C. A mixture of argon and NF_3 in a ratio of 5:1 were flowed into the chamber at a rate of 60 sccm. The chamber was maintained at a pressure of 10 milliTorr. A plasma of 15 watts was ignited and maintained in the chamber for a period of 1 minute after which the plasma was extinguished and the flow of NF_3 shut off. Argon gas was then allowed to flow through the chamber of an additional 10 seconds to remove any residues remaining in the chamber from the cleaning process.

The cleaned wafer was then moved from the plasma etch cleaning chamber through an air-tight passageway, through which argon was flowing at a rate of 10 sccm, into a previously cleaned CVD chamber where it was placed on a susceptor.

A 1 micron layer of CVD tungsten was then selectively deposited over the exposed silicon portions on the cleaned patterned wafer. The temperature of the wafer and the susceptor during the deposition was maintained at about 300° C. During the deposition WF_6 gas was flowed into the chamber at about 10 sccm, SiH_6 was flowed into the CVD chamber at about 7 sccm, and about 100 sccm of argon was also flowed into the chamber. A pressure of about 80 milliTorr was maintained in the chamber during the deposition. The deposition was carried out for a period of about 2 minutes to provide the 1 micron selective layer of tungsten on the unmasked portions of the wafer.

After the selective deposition of tungsten on each of the masked wafers was completed, each wafer was removed from the CVD chamber. The wafers were sectioned and examined under a scanning electron microscope (SEM) to measure the thickness of the deposited coatings, the surface roughness, and the selectivity of the deposition. The thickness of the coating on the various wafers was found to be substantially uniform with less than 10% variance in thickness from one wafer to another as well as across the surface of any particular wafer. The surface of the deposited tungsten appeared to be smooth on each wafer, and little, if any, evidence of tungsten deposition on the non-silicon surfaces was noted.

Example II

Several patterned silicon wafers, having exposed aluminum surfaces, were first cleaned in the same manner as were the wafers in Example I, except that BCl_3 was used as the cleaning gas and the power level of the plasma was raised to 50 watts.

As in Example I, the cleaned wafer was then moved from the plasma etch cleaning chamber through an air-tight passageway, through which argon was flowing at a rate of 10 sccm, into the previously cleaned CVD chamber.

A 1 micron layer of CVD tungsten was then selectively deposited over the exposed aluminum portions on the clean1 micron layer of CVD tungsten was then selectively deposited over the exposed aluminum portions on the cleaned patterned wafer using the same tungsten deposition conditions as in Example I.

After the selective deposition of tungsten on each of the masked wafers was completed, each wafer was removed from the CVD chamber. The wafers were sectioned and examined under a 400X optical microscope. The thickness of the tungsten coating on the various wafers was again found to be substantially uniform. The surface of the tungsten deposited over the cleaned aluminum surfaces appeared to be smooth on each wafer, and no tungsten depositions on the oxide mask surfaces of the wafer were evident.

Thus, the invention provides an improved process for the selective deposition of tungsten reproducibly on masked semiconductor wafers by cleaning each wafer in a cleaning chamber, such as, for example, a plasma etching or an RIE chamber, to remove contaminants, including moisture, from the surface of the wafer, as well as the mask surface, then transferring the cleaned wafer to a CVD chamber without reexposing the cleaned wafer to contaminants by passing the cleaned wafer from the cleaning chamber to the CVD chamber through an air-tight passageway between the two chambers, and then selectively depositing the tungsten on the wafer in the CVD chamber using a tungsten-containing gas and a reducing gas.

It will be appreciated by a skilled person that the instant invention is not only applicable for deposition of tungsten but also for any similar material with appropriate adaptions of the parameters and substances, as the cleaning gas, involved.

Claims

1. A process for the selective deposition of tungsten or similar materials on a masked semiconductor wafer (100) which comprises:
   a) cleaning the surfaces of the wafer (100) in an air-tight cleaning chamber (10); and
   b) then transferring the cleaned wafer (100) to a vacuum deposition chamber (40) for selective deposition of tungsten thereon without exposing the cleaned wafer (100) to conditions which would recontaminate the cleaned wafer (100) prior to said deposition.

2. The process of claim 1, wherein said transferring step further comprises transferring said cleaned wafer (100) from said cleaning chamber (10) to said vacuum deposition chamber (40) through an air-tight passageway (70) maintained at a vacuum of from about 10^{-2} to about 10^{-5} milliTorr.

3. The process of claim 1 or 2, wherein said transferring step further comprises transferring said cleaned wafer (100) from said cleaning chamber (10) to said vacuum deposition chamber (40) through an air-tight passageway (70) between said respective chambers (10, 40) while flowing through said passageway (70) at a rate of at least about 20 sccm one or more non-oxidizing gases, preferably argon, helium, nitrogen, hydrogen, or mixtures of same.

4. The process for the selective deposition of any of claims 1 to 3, wherein during cleaning the surfaces of the wafer (100) the cleaning chamber (10) is maintained at a pressure within a range of from about 1 milliTorr to about 760 Torr and at least one cleaning gas, preferably hydrogen or a halogen-containing gas is flowed into said chamber (10), while maintaining said wafer (100) at a temperature within a range of from about 20 to about 100 ° C, preferably to about 80 ° C.

5. The process of any of claims 1 to 4, wherein after transferring the cleaned wafer (100) from the cleaning chamber (10) to the vacuum deposition chamber (40) through the air-tight passageway (70) a vacuum deposition layer of tungsten is selectively deposited on the unmasked surfaces of the wafer (100) by flowing a tungsten-containing gas and a reducing gas through said vacuum deposition chamber (40).

6. The process of any of claims 1 to 5, wherein said cleaning step further comprises maintaining a plasma within said cleaning chamber (10) within a range of from about 1 to about 1000 watts, preferably 20 to 100 watts, during said cleaning step and maintaining the pressure in said cleaning chamber (10) within a range of from about 1 milliTorr to about 500 milliTorr during said cleaning step.

7. The process of claim 5 or 6, wherein said tungsten-containing gas is WF_6 and said reducing gas is H_2 or SiH_4.

8. The process of any of claims 1 to 7, including the additional step of flowing, preferably while maintaining said plasma, a non-reactive gas through said cleaning chamber (10) after said cleaning step for a period of at least about 5 seconds after shutoff of the flow of said cleaning gas into said cleaning chamber (10) to remove any residues remaining from said cleaning step.

9. The process of any of claims 1 to 8, wherein a gas mixture comprising a cleaning gas, preferably H_2, BCl_3, SF_6, and/or NF_3 is flown into said cleaning chamber (10) for from about 20 to about 300 seconds.

10. Apparatus for the selective deposition of tungsten or similar materials on a masked semiconductor wafer (100) comprising:

a) means for cleaning the surfaces of the wafer (100) in a cleaning chamber (10) maintained at a pressure preferably within a range of from about 1 milliTorr to about 760 Torr, comprising means (20, 22) for flowing at least one cleaning gas into said cleaning chamber (10), and means (15) for maintaining said wafer (100) at a temperature within a range of preferably from about 20 to about 100 ° C;

b) means for transferring the cleaned wafer (100) from the cleaning chamber (10) to a vacuum deposition chamber (40) comprising an air-tight passageway (70) between said respective chambers (10, 40) to exclude moisture or oxidizing gases to thereby permit subsequent selective tungsten deposition on the clean surfaces on the wafer (100) without exposing the cleaned wafer (100) to conditions which would recontaminate the cleaned wafer (100) prior to said selective deposition; and

c) means (50, 52) for selectively depositing a layer of tungsten on the unmasked surfaces of the wafer (100) comprising a tungsten-containing gas and a reducing gas flowing through said vacuum deposition chamber (40).

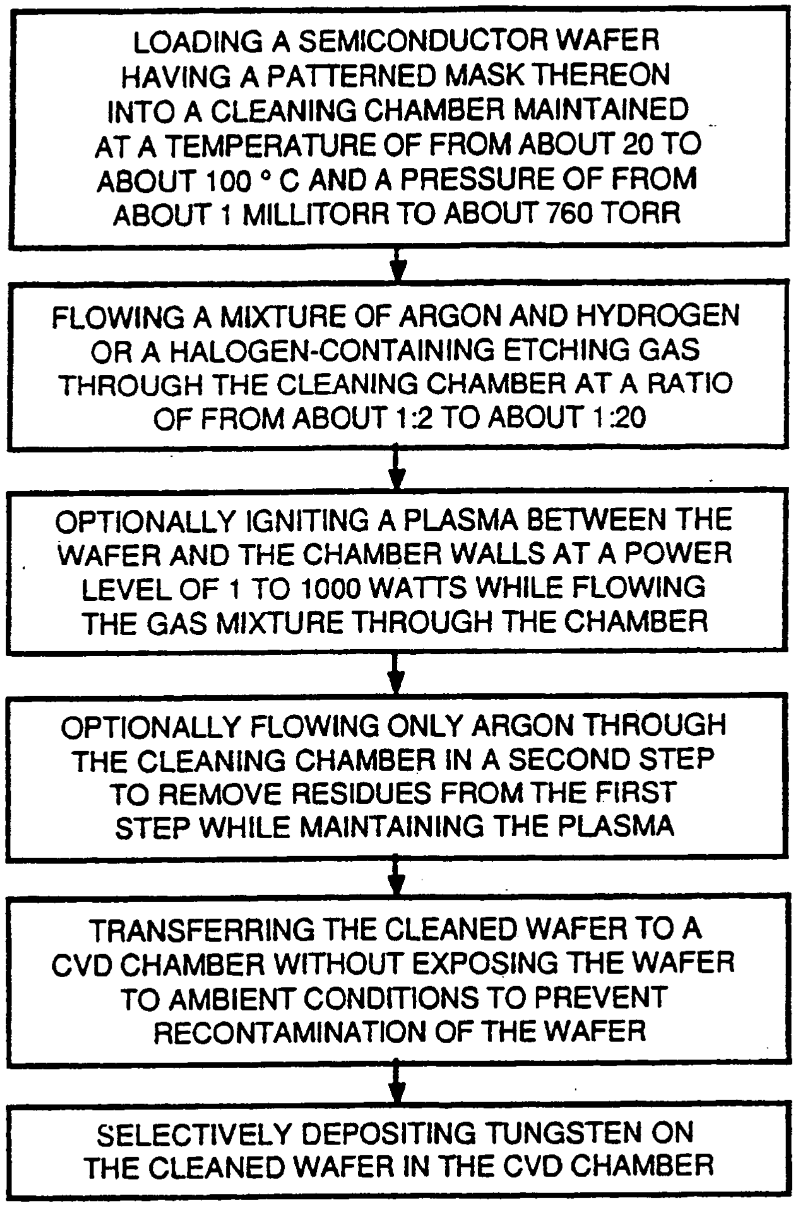
LOADING A SEMICONDUCTOR WAFER HAVING A PATTERNED MASK THEREON INTO A CLEANING CHAMBER MAINTAINED AT A TEMPERATURE OF FROM ABOUT 20 TO ABOUT 100 ° C AND A PRESSURE OF FROM ABOUT 1 MILLITORR TO ABOUT 760 TORR
FLOWING A MIXTURE OF ARGON AND HYDROGEN OR A HALOGEN-CONTAINING ETCHING GAS THROUGH THE CLEANING CHAMBER AT A RATIO OF FROM ABOUT 1:2 TO ABOUT 1:20
OPTIONALLY IGNITING A PLASMA BETWEEN THE WAFER AND THE CHAMBER WALLS AT A POWER LEVEL OF 1 TO 1000 WATTS WHILE FLOWING THE GAS MIXTURE THROUGH THE CHAMBER
OPTIONALLY FLOWING ONLY ARGON THROUGH THE CLEANING CHAMBER IN A SECOND STEP TO REMOVE RESIDUES FROM THE FIRST STEP WHILE MAINTAINING THE PLASMA
TRANSFERRING THE CLEANED WAFER TO A CVD CHAMBER WITHOUT EXPOSING THE WAFER TO AMBIENT CONDITIONS TO PREVENT RECONTAMINATION OF THE WAFER
SELECTIVELY DEPOSITING TUNGSTEN ON THE CLEANED WAFER IN THE CVD CHAMBER

Fig 1

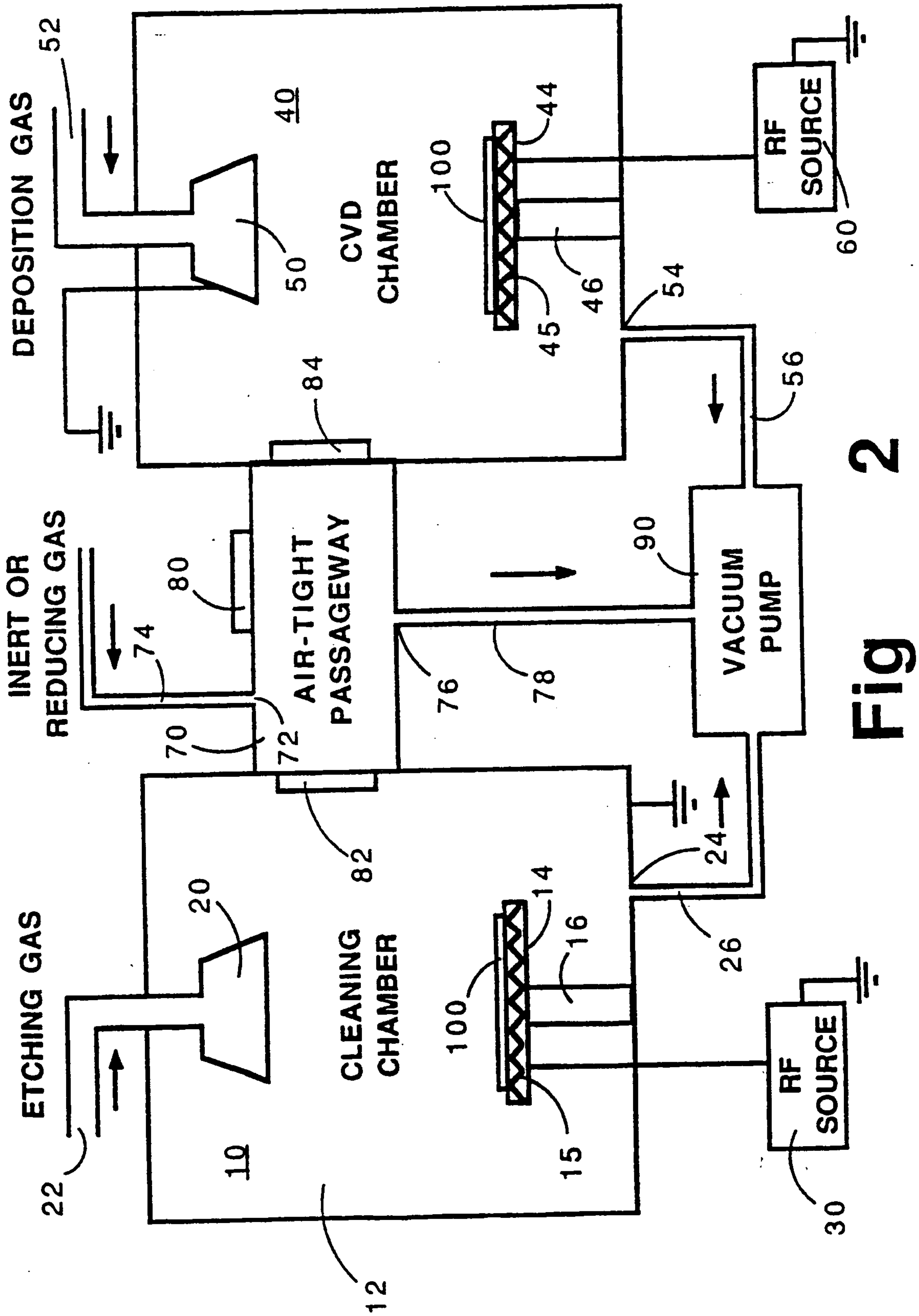
DEPOSITION GAS
52
40
CVD CHAMBER
50
100
44
45
46
RF SOURCE
60
54
56
84
INERT OR REDUCING GAS
80
74
70
72
AIR-TIGHT PASSAGEWAY
76
78
90
VACUUM PUMP
82
ETCHING GAS
22
20
CLEANING CHAMBER
10
12
100
14
16
15
24
26
RF SOURCE
30

Fig 2

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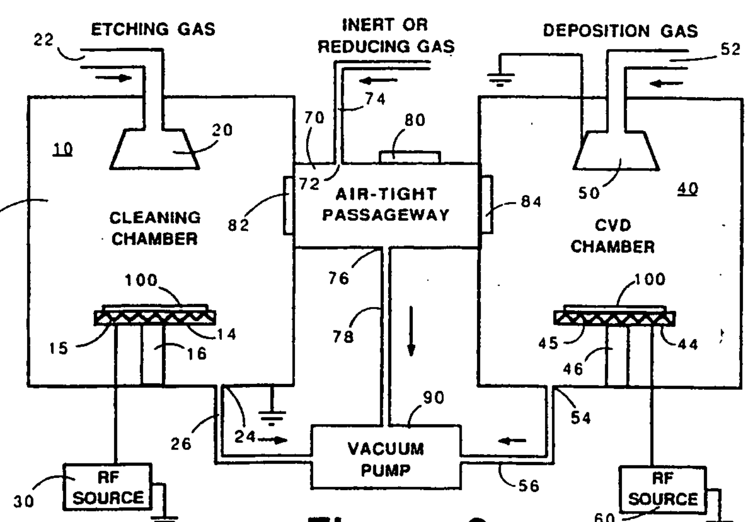

Fig 2

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 12 3025

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US-A-4 605 479 (RCA CORP.) * column 1, line 63 - line 68 * * column 2, line 61 - column 4, line 30 *	1,8,10	H01L21/285 H01L21/306 H01L21/311
X	GB-A-2 181 297 (SGS MICROELECTRONICS S.P.A.) * page 2, line 34 - line 62 * * page 2, line 68 - line 116 * * page 3, line 3 - line 55 *	1,4,6, 9-10	
A	US-A-4 629 635 (GENUS INC.) * column 6, line 11 - column 7, line 28 *	1,3,5,7, 9	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 348 (E-799)4 August 1989 & JP-A-1 108 723 (MATSUSHITA ELECTRIC IND CO LTD) 26 April 1989 * abstract *	1,5,7	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H01L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	03 SEPTEMBER 1992	SCHUERMANS N.

CATEGORY OF CITED DOCUMENTS

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